1. Name of Experiment/Project/Collaboration: IsoDAR
2. Physics Goals
    a. Primary: Sterile neutrino search through anti-electron-neutrino disappearance
    b. Secondary: antineutrino-electron scattering to search for non-standard interactions. We also have other programs (eg. LV searches, etc.)
3. Expected location of the experiment/project: KamLAND, WATCHMAN, JUNO, ASDC, Other > 1 kt LS detectors
4. Neutrino source: 8Li decay
5. Primary detector technology: >1 kt, LS detectors. Primary source technology is isotope decay-at rest.
6. Short description of the detector –

    Here we describe the source, which is the subject of the IsoDAR program:

    5 mA of H2+ (equivalent to 10 mA of protons) are accelerated to 60 MeV. The ions are directed onto a Be target, which is embedded in a sleeve containing 7Li that is >99.99% pure. Interactions of the protons in the Be target produce neutrons that bathe the sleeve, producing 8Li. This decays to produce anti-electron-neutrinos with a well understood beta-decay energy spectrum and an endpoint of 13 MeV. The x and y distribution of production points at the source have a σ = 23 cm, and the z distribution has σ = 37 cm. In the case of a pairing with KamLAND, the source is place 16.5 m from the center of the detector.
7. List key publications and/or archive entries describing the project/experiment.
    1) **Proposal for an Electron Antineutrino Disappearance Search Using High-Rate ^{8}Li Production and Decay** - Bungau, A. *et al.* Phys.Rev.Lett. 109 (2012) 141802 arXiv:1205.4419 [hep-ex]
    2) **Electron Antineutrino Disappearance at KamLAND and JUNO as Decisive Tests of the Short Baseline Anti-nu_mu to Anti-nu_e Appearance Anomaly** - Conrad, J.M. *et al.* Phys.Rev. D89 (2014) 057301 arXiv:1310.3857 [hep-ex]
    3) **Precision $\bar{\nu}_e$-electron scattering measurements with IsoDAR to search for new physics** - Conrad, J.M. *et al.* Phys.Rev. D89 (2014) 7, 072010 arXiv:1307.5081 [hep-ex]
    4) **Whitepaper on the DAEdALUS Program** - Aberle, C. *et al.* arXiv:1307.2949
8. Collaboration
    a. Institution list

    US Academic Institutions: Amherst College, Columbia University, Duke University, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Massachusetts Institute of Technology, Michigan State University, New Mexico State University, University of California, Berkeley (Nuclear Engineering), University of California, Irvine, University of California, Los Angeles, University of Maryland, University of Tennessee

    International Academic Institutions: LNS-INFN (Catania), The Cockcroft Institute for Accelerator Science & the University of Manchester, Imperial College London, Paul Scherrer Institute, University of Huddersfield,, RIKEN, Tohoku University

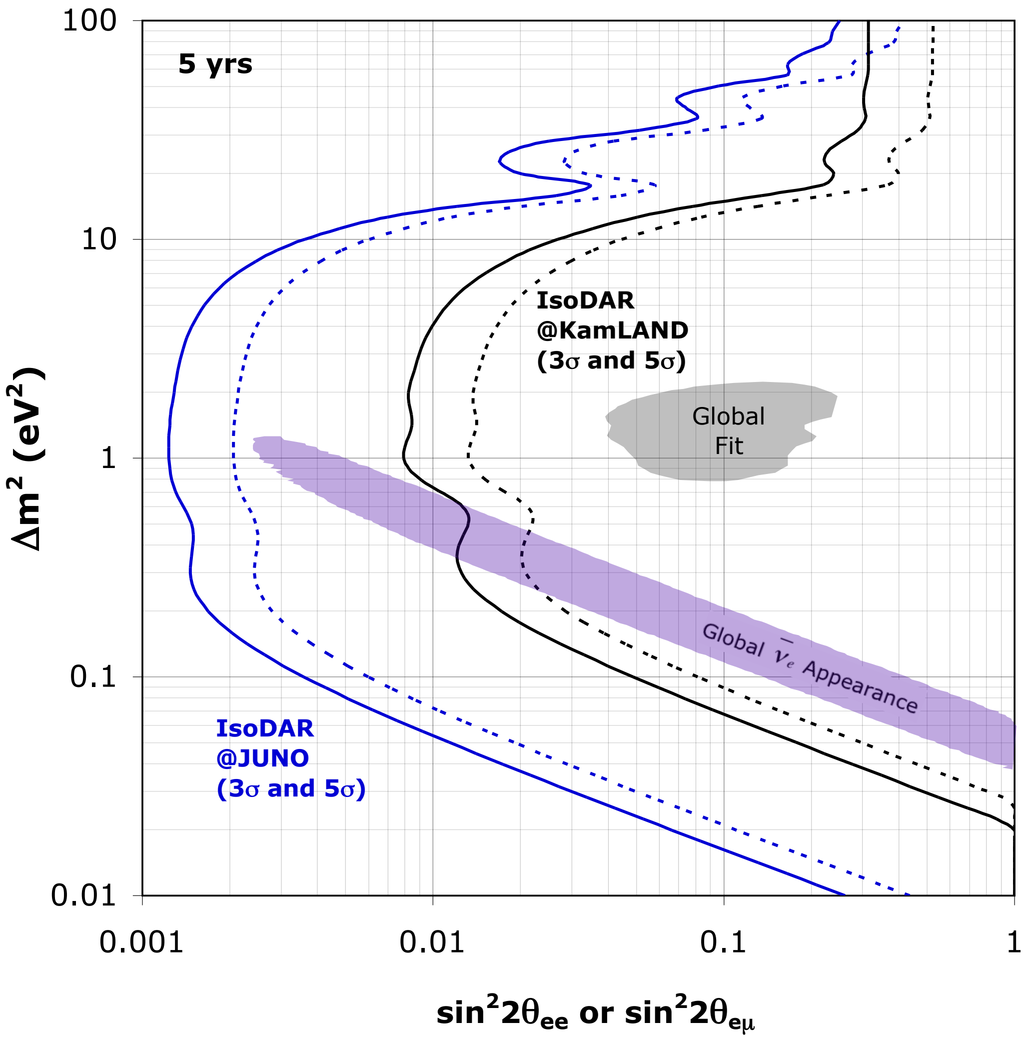
    Industrial Institutions: AIMA, Best Cyclotron Systems, IBA

    b. Number of present collaborators : 50
    c. Number of collaborators needed.: 50 or more

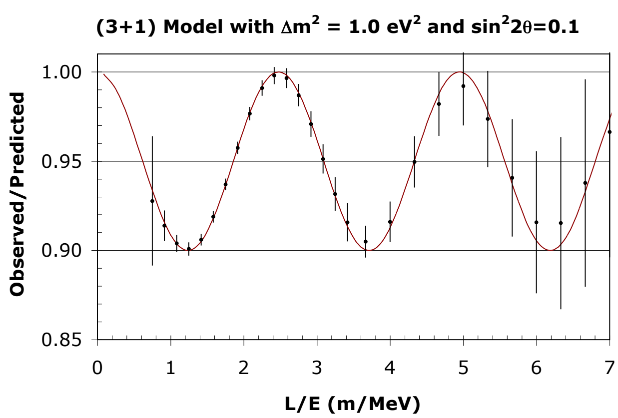
9. R&D
    a. List the topics that will be investigated and that have been completed
       Our R&D requirements were vetted by an external committee in the Galambos Report: (http://arxiv.org/abs/1308.4719). Since then, we have been working to address the issues. The most crucial issue for both IsoDAR and DAEdALUS is production of a well-benchmarked start-to-end simulation. The studies for this, and the code, were completed in Fall 2014, and a paper will be submitted in early 2015. Other issues included: demonstration of the ion source (75% complete), demonstration of the unusually large spiral inflector (100% complete), establishment of the LEBT (100% complete) and studies of high power targeting on beryllium, 20% complete.
    b. Which of these are crucial to the experiment: All are crucial and most have been addressed. We are seeking funds for the high power targeting R&D studies. We are seeking funding to build final-prototypes that we plan to install as first working devices for the ion source, LEBT and the spiral inflector. Along with these items, what is crucial to the experiment is to obtain funding for engineering for the final cyclotron design.
    c. Time line: A technically driven schedule completes the source in 2019.
    d. Benefit to future projects: We are building a source which is useful when paired with many detectors. So this has substantial impact on the future opportunities in the HEP community. Beyond this, our work is having a major impact in the cyclotron community. For example, the OPAL code, which is the equivalent of GEANT4 of that community, now has capability to describe spiral inflectors in 3-D due to our work. We also note that establishing a cyclotron of the design we propose has been defined by DOE as in the national interest due to the medical applications. See Cost / Benefit Comparison For 45 MeV and 70 MeV Cyclotron conducted by Jupiter Technical, Security and Management Solutions for the U.S. Department of Energy, Office of Nuclear Science, Energy and Technology, www.isotopes.gov/outreach/reports/Cyclotron.pdf (2005).

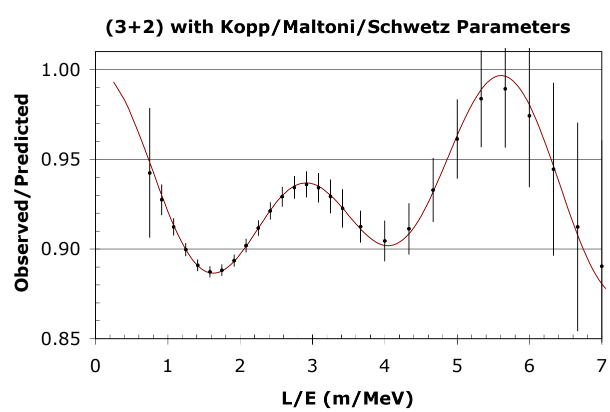
10. Primary physics goal expected results/sensitivity:

    a. For exclusion limit (such as sterile neutrino search), show 3-sigma and 5-sigma limits
       The experiment has direct sensitivity to anti-electron neutrino disappearance. In models with CPT conservation, these limits also directly bear on anti-muon neutrino to anti-electron neutrino searches. For this reason, we overlay our sensitivities on the current disappearance and appearance signal regions. The limits are for 5 years of running, with the assumptions given in references 1 and 2 listed above under question 7.

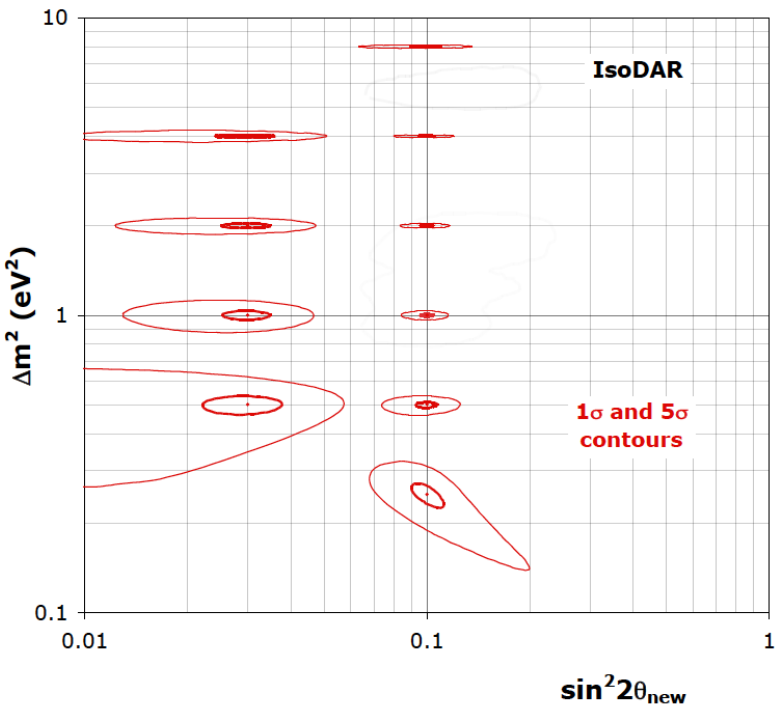


b. For discovery potential (such as the Mass Hierarchy), show 3-sigma and 5-sigma.
   The primary sensitivity is coming from shape analysis. Here are two example signals for 5 yrs of data:





The result of this sensitivity is the following "Jelly bean" plot for measurements for IsoDAR at KamLAND with 5 yrs of data, where we show 1σ and 5σ:



c. For sensitivity plots, show 3-sigma and 5-sigma sensitivities
(note that for neutrino-less double beta decay experiments that have previously been asked for 90% CL and 5 sigma limits these are OK)
Our exclusion limit and sensitivity are identical.

d. List the sources of systematic uncertainties included in the above, their magnitudes and the basis for these estimates.
These experiments have very high signal to background because of the rates and excellent control of the background systematics through the shape analysis. Therefore the primary systematics arise from the resolutions on energy and position. The position error comes from the target production described in question 6 (which, at 1σ, is 23 cm in x,y and 37 cm in z) and from vertex reconstruction which is 12cm/sqrt(E) in KamLAND. The energy resolution is 6.4%/sqrt(E) in KamLAND. This is a well understood detector and these numbers are well known. The "wave plot", shown in the answer to 10 b., displays the resolution effects by comparing the L/E dependence for IsoDAR@KamLAND (points) to the L/E with no smearing (red line). References 1-4 provide details on the systematics and systematic errors are included in our limit and signal plots listed above.

e. List other experiments that have similar physics goals
There is a set of reactor-based experiments seeking to do anti-electron-neutrino disappearance and a set of source experiments that seek to do electron-neutrino disappearance studies.

f. Synergies with other experiments.
   The design of our experiment is unique and complementary to the other experiments in the following ways: 1) The energy range is substantially higher than reactor or source experiments and the flux is very high and very pure, leading to very high signal to background. 2) Our schedule for running is very flexible – we can run as long as is needed and we can turn the beam on and off as appropriate for the analysis and background studies.

11. Secondary Physics Goal
    a. Expected results/sensitivity
       Here we will focus on the anti-electron neutrino—electron scattering program (Ref 3), although this is one of several secondary programs. The purpose of this program is to constrain possible non-standard interactions. To present the sensitivity, for simplicity, we provide plots from Ref. 3. If it is requested, we can remake the plots for whatever sensitivity is requested.

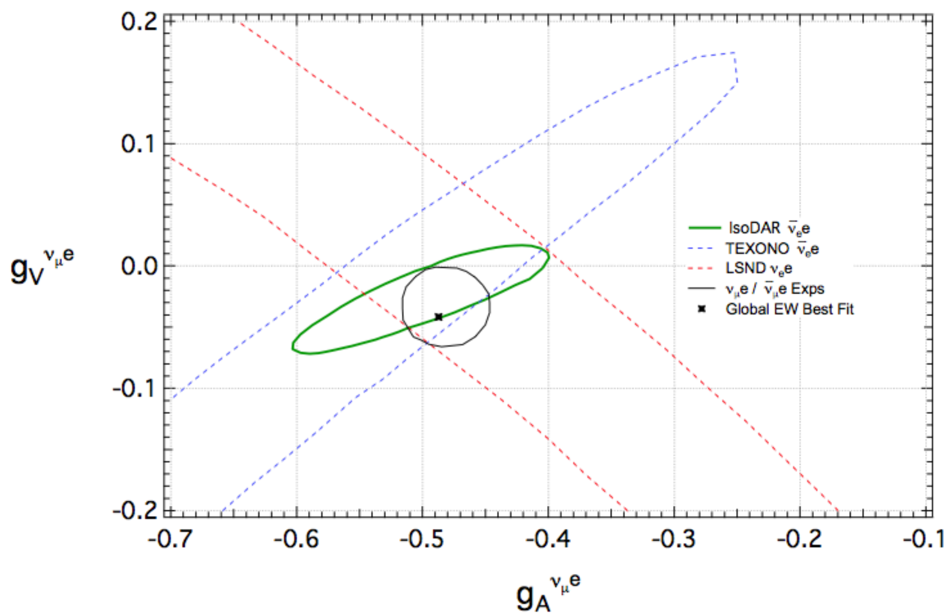


FIG. 2: IsoDAR's sensitivity to g_V and g_A along with allowed regions from other neutrino scattering experiments and the electroweak global best fit point taken from Ref. [37]. The IsoDAR, LSND, and TEXONO contours are all at 1σ and are all plotted in terms of $g_{V,A}^{\nu_\mu e} = g_{V,A}^{\nu_e e} - 1$ to compare with ν_μ scattering data. The $\nu_\mu e/\bar{\nu}_\mu e$ contour is at 90% C.L.

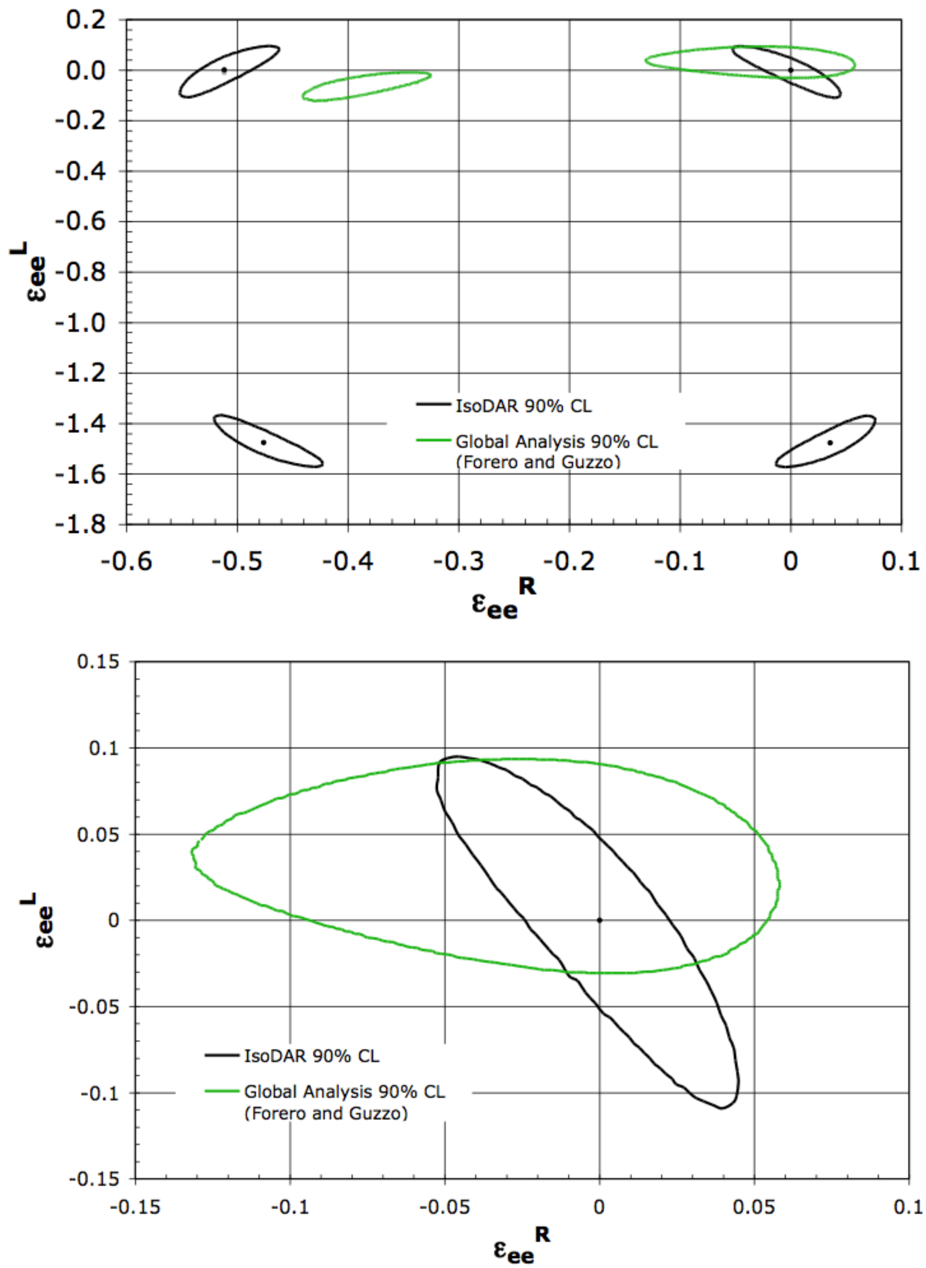


FIG. 3: (Top) IsoDAR's sensitivity to ϵ_{ee}^{eL} and ϵ_{ee}^{eR}. The current global allowed region, based on Ref. [38] is also shown. (Bottom) A zoomed-in version of the top plot, emphasizing the region near ϵ_{ee}^{eL} and $\epsilon_{ee}^{eR} \sim 0$ is shown.

b. List other experiments that have similar physics goals
The SOX experiment has proposed to pursue this during Phase C running with a goal of similar sensitivity. See doi:10.1007/JHEP08(2013)038.

12. Experimental requirements
    a. Provide requirements (neutrino source, intensity, running time, location, space,…) for each physics goal
    For the sterile neutrino search, we provide the parameters associated with KamLAND running, taken from Ref. 1:

Accelerator	60 MeV/amu of H_2^+
Current	10 mA of protons on target
Power	600 kW
Duty cycle	90%
Run period	5 years (4.5 years live time)
Target	^{9}Be surrounded by ^{7}Li (99.99%)
$\bar{\nu}$ source	^{8}Li β decay ($\langle E_\nu \rangle$=6.4 MeV)
$\bar{\nu}_e$/1000 protons	14.6
$\bar{\nu}_e$ flux	1.29×10^{23} $\bar{\nu}_e$
Detector	KamLAND
Fiducial mass	897 tons
Target face to detector center	16 m
Detection efficiency	92%
Vertex resolution	12 cm/$\sqrt{E}$ (MeV)
Energy resolution	6.4%/$\sqrt{E}$ (MeV)
Prompt energy threshold	3 MeV
IBD event total	8.2×10^5
$\bar{\nu}_e$-electron event total	7200

TABLE I: The relevant experimental parameters used in this study.

For the elastic scattering search, we also assume the KamLAND scenario with parameters in the above table with the addition of the following requirements to reduce backgrounds from Ref 3:

Muon Veto	
All muons	$\Delta T_\mu > 200$ ms
Well-tracked muons	$\Delta T_\mu > 5$ s for $\Delta R_\mu < 3$ m
Poorly-tracked muons	$\Delta T_\mu > 5$ s
ES Selection Cuts	
$E_{\rm vis} > 3$ MeV	
$R < 5.0$ m	
IBD Veto	
Events with $E^d_{\rm vis} > 1.8$ MeV	$\Delta T_d > 2$ ms for $R_d < 6.0$ m

TABLE II: Summary of cuts used to reduce the ES backgrounds. The symbols are defined in the text. The phrase "poorly-tracked muons" above also refers to muons which produce unusually high light levels. Further details can be found in the text.

Further information is provided within the references or can be added upon request

13. Expected Experiment/Project time line
    a. Design and development
       This is well underway. We have many published papers on the design and have run many studies. Our goal is to produce a CDR by end of 2015. Whether we can meet this goal is a matter of the question of obtaining engineering funding.
    b. Construction and Installation
       A technically driven schedule allows us to be installed at KamLAND in 2019
    c. First data
       4 months of data provides rate-only 5-sigma coverage of the full disappearance allowed region, hence 2020.
    d. End of data taking - 5 years after the start of running.
    e. Final results
       These should be more or less simultaneous with the end of running, since analyses can be done in the interim and we are using a very well understood detector, if paired with KamLAND, hence 2025.

14. Estimated cost range
    a. US contribution to the experiment/project
       $30M (and $15M contingency). At this point the majority of the costs are very well known because IBA, an internationally renowned cyclotron company, has supplied an independent cost estimate for the cyclotron (the most major piece of equipment) to compare to our internal cost estimate, and the results agreed. The IBA report is available upon request.
    b. International contribution to the experiment/project
       The above assumed no international contribution, because this is yet to be negotiated. However, we believe that we can negotiate contributions, particularly in-kind, from three international cyclotron laboratories: INFN-Catania, PSI and RIKEN. The Japanese will be asked to contribute for any renovations in the KamLAND halls.
    c. Operations cost
       These depend upon where we run. We assume if we run outside the US (at KamLAND and/or JUNO) that the host countries cover the utilities costs. Operations costs are offset by production of 82Sr, which is a product in demand for medical imaging. The AIMA group is helping the collaboration coordinate this.

15. The Future
    a. Possible detector upgrades and their motivation.
       No upgrades of the IsoDAR design are under consideration at present, but we envision making multiple sources to run at various detectors. However, the IsoDAR cyclotron has the same design as the injector for DAEdALUS, and so running IsoDAR is a Phase II goal of the overall DAEdALUS program.
    b. Potential avenues this project could open up.
       Our program of developing high power cyclotrons is unique in the US and could open a broad range of opportunities in HEP well beyond neutrino sources. In addition, these cyclotrons are of prime interest for medical isotope production and other industrial applications.